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(57) 【要約】 (修正有)

【課題】 光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器を提供する。

【解決手段】 アレイ導波路回折格子 106 と、前記入力用チャネル導波路 102 及びアレイ導波路回折格子 106 を接続する扇形の入力側スラブ導波路 104 と、前記出力用チャネル導波路 108 及び前記アレイ導波路回折格子 106 を接続する扇形の出力側スラブ導波路 107 とを設け、前記入力側スラブ導波路 104 及び前記アレイ導波路回折格子 106 の接続部、又は前記出力側スラブ導波路 107 及び前記アレイ導波路回折格子 106 の接続部のうちの少なくとも一方において、アレイ導波路格子 106 を構成する各チャネル導波路 105 の中心軸と、それぞれ隣接するチャネル導波路 105 の中心軸との間隔を、全チャネル導波路 105 にわたって徐々に変化させる。

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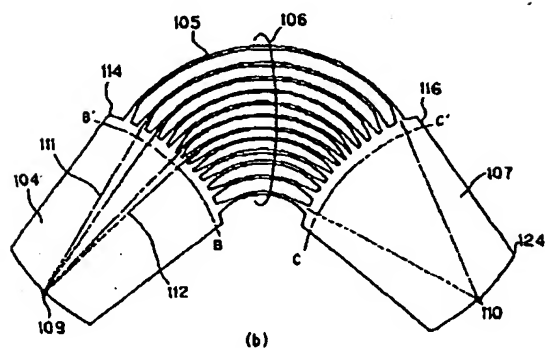
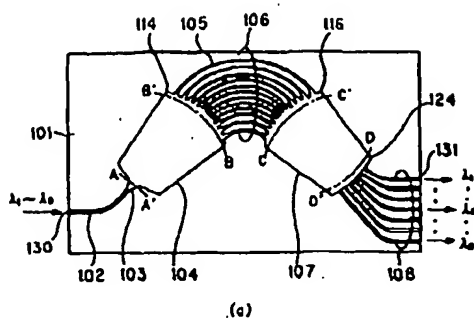
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(57) [Abstract] (There is an amendment.)

[Problem] Light wavelength divider/coupler where combination amount wave of light signal to which the loss fluctuation for wavelength fluctuation of light source is small, at the same time stabilizes is possible is offered.

[Means of Solution] Array waveguide diffraction grating 106, channel waveguide 102 for front entry power and connects array waveguide diffraction grating 106 input side slab waveguide 104 of the fan shape which, channel waveguide 108 for aforementioned output and output side slab waveguide 107 of fan shape which connects aforementioned array waveguide diffraction grating 106 to provide, It changes gradually connector of aforementioned input side slab waveguide 104 and the aforementioned array waveguide diffraction grating 106, in at least one among connector of aforementioned output side slab waveguide 107 and aforementioned array waveguide diffraction grating 106, spacing of the center axis of channel waveguide 105 which is adjacent with center axis of each channel waveguide 105 which forms array waveguide grating

106, respectively, over all channel waveguide 105.



【特許請求の範囲】

【請求項 1】 基板上に、1 本以上の入力用チャネル導波路と、1 本以上の出力用チャネル導波路と、導波路長を最短なものから最長なものへ所定の長さずつ順次長く設定した複数本のチャネル導波路で構成したアレイ導波路回折格子と、前記入力用チャネル導波路及びアレイ導波路回折格子を接続する扇形の入力側スラブ導波路と、前記出力用チャネル導波路及び前記アレイ導波路回折格子を接続する扇形の出力側スラブ導波路とを備えた光波長合分波器であって、

前記入力側スラブ導波路及び前記アレイ導波路回折格子の接続部、又は前記出力側スラブ導波路及び前記アレイ導波路回折格子の接続部のうちの少なくとも一方において、前記アレイ導波路格子を構成する各チャネル導波路の中心軸と、それぞれ隣接するチャネル導波路の中心軸との間隔を、全チャネル導波路にわたって徐々に変化させてなることを特徴とする光波長合分波器。

【請求項 2】 前記入力側スラブ導波路の前記接続部及

[Claim(s)]

[Claim 1] To on substrate, channel waveguide for input of one or more, channel waveguide and waveguide length for output of one or more shortest from the thing longest each specified length being a light wavelength divider/coupler which has with the array waveguide diffraction grating and channel waveguide for front entry power and input side slab waveguide of fan shape which connects array waveguide diffraction grating and channel waveguide for aforementioned output and output side slab waveguide of fan shape which which connects aforementioned array waveguide diffraction grating are formed with multiple channel waveguide which sequential long is set to the thing,

Changing gradually connector of aforementioned input side slab waveguide and the aforementioned array waveguide diffraction grating, in at least one among connector of aforementioned output side slab waveguide and aforementioned array waveguide diffraction grating, spacing of the center axis of channel waveguide which is adjacent with center axis of each channel waveguide which forms aforementioned array waveguide grating, respectively, over all channel waveguide, the light wavelength divider/coupler which designates that it becomes as feature.

[Claim 2] In aforementioned connector of aforementioned in

び前記出力側スラブ導波路の前記接続部において、前記アレイ導波路回折格子を構成する前記チャネル導波路を、前記入力スラブ導波路及び前記出力側スラブ導波路に沿ってそれぞれ放射状に配置し、前記各チャネル導波路の中心軸と、それぞれ隣接するチャネル導波路の中心軸との間の所定の基準点に対する角度を、全チャネル導波路にわたって徐々に変化させてなる請求項1に記載の光波長合分波器。

【請求項3】 前記アレイ導波路回折格子を構成する前記チャネル導波路の本数をN、前記各チャネル導波路の番号をi、予め定めた基準のチャネル導波路の番号jとしたとき、前記入力側スラブ導波路又は前記出力側スラブ導波路の前記接続部における第i番目の前記チャネル導波路と第i+1番目の前記チャネル導波路との間の前記所定の基準点に対する角度 $\Delta\theta_i$ を、下記式(1)に示すように、徐々に変化させてなる請求項2に記載の光波長合分波器。

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + \sum A_k \cdot |i - j|^k\} \quad \dots (1)$$

(式(1)中、 A_k は定数であり、kは1～Nの整数である。)

【請求項4】 前記式(1)において、所定の定数Aの範囲を $-0.001 \leq A_k \leq 0.001$ (kは1～Nの整数である)とした請求項3に記載の光波長合分波器。

【請求項5】 前記式(1)において、前記アレイ導波路回折格子を構成するチャネル導波路の本数(N)を1とすることにより、前記角度 $\Delta\theta_i$ を下記式(2)に示すものとした請求項3又は4に記載の光波長合分波器。

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + A_1 \cdot |i - j|\} \quad \dots (2)$$

(式(2)中、 A_1 は定数であり、 $A_1 \neq 0$ である。)

【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、光波長合分波器に

put side slab waveguide and aforementioned connector of aforementioned output side slab waveguide putting. Aforementioned channel waveguide which forms aforementioned array waveguide diffraction grating changing gradually angle for specified reference point with center axis of channel waveguide which arranges respectively in radial alongside front entry power slab waveguide, and aforementioned output side slab waveguide is adjacent with center axis of aforementioned each channel waveguide, respectively, over all channel waveguide, the light wavelength divider/coupler which it states in explanation/learning seeking Claim 1 which becomes.

[Claim 3] Number of aforementioned channel waveguide which forms aforementioned array waveguide diffraction grating N, When number of aforementioned each channel waveguide i, making then number j of channel waveguide of standard which is decided beforehand, as shown the angle θ_i for aforementioned specified reference point with aforementioned channel waveguide of i'th in aforementioned input side slab waveguide or aforementioned connector of aforementioned output side slab waveguide and aforementioned channel waveguide of i'th + first, in below-mentioned Formula (1), changing gradually, light wavelength divider/coupler which it states in Claim 2 which becomes.

$$\theta_i = \theta_j \cdot \{1 + A_k \cdot |i - j|^k\} \quad \dots (1)$$

(Formula (1) In, A_k is constant, k is integer of 1 to N.)

[Claim 4] In aforementioned Formula (1), range of specified constant A - 0.001 A_k 0.001 (k is integer of 1 to N.) with the light wavelength divider/coupler which is stated in Claim 3 which is done.

[Claim 5] Light wavelength divider/coupler which is stated in Claim 3 or 4 show aforementioned angle θ_i in below-mentioned Formula (2) in aforementioned Formula (1), by designating number (N) of channel waveguide which forms aforementioned array waveguide diffraction grating as 1.

$$\theta_i = \theta_j \cdot \{1 + A_1 \cdot |i - j|\} \quad \dots (2)$$

(Formula (2) In, A_1 is constant, is $A_1 \neq 0$.)

[Description of the Invention]

[0001]

[Technological Field of Invention] This invention regards light

関し、特に、光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器に関する。

[0002]

【従来の技術】光波長多重通信において、波長の異なる複数の光信号の合波又は分波（合分波）をする光波長合分波器としてアレイ導波路回折格子が有望視され、種々提案されている（特開平4-116607号公報、特開平4-1634064、特開平4-220624号公報、特開平4-3263084号公報、特開平5-157920号公報）。特に、通過帯域特性を平坦化したアレイ導波路回折格子型光波長合分波器は、光源の波長変動等に対する挿入損失の変動が小さく、安定した光信号の合分波が可能であるため、光波長多重通信に有用なデバイスとして期待されている（米国特許第5412744号）。

【0003】図7は、従来のアレイ導波路回折格子型光波長合分波器を模式的に示す説明図である。ここでは、一例として、9つの光信号 $\lambda_1 \sim \lambda_9$ ($\lambda_1 < \lambda_2 < \dots < \lambda_8 < \lambda_9$) を合分波するための光波長合分波器を示す。図7に示すように、従来の光波長合分波器は、基板201上に、入力導波路202と、入力側スラブ導波路204と、長さが後述する ΔL ずつ異なる複数のチャンネル導波路205で形成したアレイ導波路回折格子206と、出力側スラブ導波路207と、9本の出力導波路208とから形成されている。また、入力導波路202と入力側スラブ導波路204の接続部には損失波長特性の通過帯域特性を平坦化するためのモード変換部203が形成されている。

【0004】図8は、従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の電界分布を模式的に示す説明図であり、図8(a)は、モード変換部203のE-E'における光信号の電界分布209、図8(b)は、アレイ導波路回折格子入射端210のF-F'における電界分布211、図8(c)は、アレイ導波路回折格子出射端212のG-G'での電界分布21

wavelength divider/coupler, it regards light wavelength divider/coupler where the combination amount wave of light signal to which especially, loss fluctuation for wavelength fluctuation of light source is small, at the same time stabilizes is possible.

[0002]

[Prior Art] That array waveguide diffraction grating is promising in light wavelength multiple communication, as light wavelength divider/coupler which does the combination wave or amount wave (Combination amount wave) of light signal of plural where the wavelength differs it is considered, various is proposed (Japan Unexamined Patent Publication Hei 4-116607 disclosure, Japan Unexamined Patent Publication Hei 4-1634064, Japan Unexamined Patent Publication Hei 4-220624 disclosure, Japan Unexamined Patent Publication Hei 4-3263084 disclosure and Japan Unexamined Patent Publication Hei 5-157920 disclosure). Especially, because combination amount wave of light signal to which as for array waveguide diffraction grating type light wavelength divider/coupler which passing domain characteristic planarization is done, fluctuation of insertion loss for wavelength fluctuation etc of light source is small, stabilizes is possible, it is expected to light wavelength multiple communication as the useful device (U. S. Patent No. 5412744 number).

[0003] Figure 7 is explanatory diagram which shows conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic. Here, 9 horn light signal 1 to 9 ($1 < 2 < \dots < 8 < 9$) light wavelength divider/coupler in order combination amount wave to do is shown as one example. As shown in Figure 7, conventional light wavelength divider/coupler, on substrate 201, at a time input waveguide 202 and L which input side slab waveguide 204 and length mention later is formed from output waveguide 208 of array waveguide diffraction grating 206 and output side slab waveguide 207 and 9 book which were formed with channel waveguide 205 of plural which differs. In addition, mode converting part 203 in order planarization to do passing limit characteristic of loss wavelength characteristic to input waveguide 202 and connector of input side slab waveguide 204 is formed.

[0004] As for Figure 8, it is a explanatory diagram which shows electric field distribution of light signal in the specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, as for Figure 8(a), the electric field distribution 209 of light signal in E-E' of mode converting part 203, as for Figure 8(b), the electric field distribution 211 and Figure 8(c) in F-F' of array waveguide

3をそれぞれ示す。

【0005】図9は、従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布を模式的に示す説明図であり、図9(a)、図9(e)、図9(f)は、アレイ導波路回折格子出射端212のG-G'での光信号 λ_1 、 λ_5 、 λ_9 のそれぞれの位相分布214、215、216を示す。

【0006】図10は、従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布の差を模式的に示す説明図であり、図10(a)及び図10(b)は、光信号 λ_1 、 λ_9 の位相面214、216と λ_5 の位相面215とのそれぞれの位相分布の差217、218を示す。

【0007】図11は、従来のアレイ導波路回折格子型光波長合分波器の集光面219のH-H'における光信号 λ_1 、 λ_5 、 λ_9 の電界分布220、221、222を模式的に示す説明図である。

【0008】以下、図7を用い、かつ適宜他図を参照して、従来の光合分波器の作用を説明する。なお、アレイ導波路回折格子206を構成するチャンネル導波路205の隣接間の導波路長差 ΔL は、下記式(3)で設計されているものとする。

$$\Delta L = 2 \cdot m \cdot \pi / \beta(\lambda_5) \quad \dots (3)$$

(式(3)中、 m は回折次数(正の整数)を示し、 $\beta(\lambda_5)$ は光信号 λ_5 に対するチャンネル導波路の伝搬定数を示す。)

【0009】入力導波路202から入射された光信号 $\lambda_1 \sim \lambda_9$ は、モード変換部203、入力スラブ導波路204、アレイ導波路回折格子205、出力スラブ導波路207、出力導波路208の順で伝搬する。

【0010】図8(a)に示すように、モード変換部203のE-E'における光信号の電界分布209は、左右対称の双峰状である。

【0011】図8(b)に示すように、入力スラブ導波路204のアレイ導波路回折格子206の入射端210のF-F'における電界分布211は、回折の効果で恒

定電界分布213で、G-G'の光信号の電界分布212で、それぞれ示す。

[0005] As for Figure 9, it is an explanatory diagram which shows phase distribution of light signal in the specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, Figure 9(a), Figure 9(e) and Figure 9(f), light signal 1 with G-G' of array waveguide diffraction grating emitting end 212, show the respective phase distribution 214, 215, 216 of 5 and 9.

[0006] As for Figure 10, it is an explanatory diagram which shows difference of the phase distribution of light signal in specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, the Figure 10(a) and Figure 10(b), show difference 217, 218 of respective phase distribution of phase surface 214, 216 of light signal 1 and 9 and the phase surface 215 of 5.

[0007] As for Figure 11, it is an explanatory diagram which shows electric field distribution 220, 221, 222 of light signal 1, the 5 and 9 in H-H' of light collection surface 219 of the conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic.

[0008] Below, making use of Figure 7, at same time referring to as needed other figure, you explain action of conventional optical divider/coupler. Furthermore, waveguide long difference L between the adjacent of channel waveguide 205 which forms array waveguide diffraction grating 206 are designed with the below-mentioned Formula (3).

$$L = 2 \cdot m \cdot \pi / \beta(\lambda_5) \quad \dots (3)$$

(Formula (3) In, m shows diffraction degree (positive integer), $\beta(\lambda_5)$ shows transmission general constant of channel waveguide for light signal 5.)

[0009] From input waveguide 202 light signal 1 to 9 which incidence is done, mode converting part 203 and the input slab waveguide 204, array waveguide diffraction grating 205 and output slab waveguide 207, propagation does in order of output waveguide 208.

[0010] As shown in Figure 8(a), electric field distribution 209 of light signal in E-E' of the mode converting part 203 is binodal condition of left-right symmetry.

[0011] As shown in Figure 8(b), electric field distribution 211 in F-F' of incident edge 210 of the array waveguide diffraction grating 206 of input slab waveguide 204 becomes distribution

大値、極小値をもつ分布となる。アレイ導波路回折格子の入射端 210 の F-F' において、光信号は分割され、各チャネル導波路 206 を入射・伝搬する。

【0012】図 8 (c) に示すように、アレイ導波路回折格子 205 の終端 212 の G-G' における電界分布 213 は、各信号ともに入射端 210 の F-F' での電界分布 211 を再現する。

【0013】図 9 (a)、(b)、(c) に示すように、終端 212 の G-G' における光信号 $\lambda_1 \sim \lambda_9$ の位相面 214 は、光信号によって異なっている。ここで、前記式 (3) より、光信号 λ_5 の位相面 215 は左右対称となり、他の光信号の位相面は、アレイ導波路回折格子終端 219 の H-H' に対して、その伝搬定数に応じた傾きを生じる。

【0014】図 10 に示すように、位相差はアレイ導波路回折格子 206 のチャネル導波路 205 において連続的に変化している。各光信号は、出力スラブ導波路 207 において、この傾きに応じた方向に伝搬する。したがって、各光信号は出力スラブ導波路 207 の集光面 219 の異なる点 $Y_1 \sim Y_9$ (図示せず) にそれぞれ集光する。

【0015】ここで、図 11 に示すように、集光面 219 の H-H' における各信号の電界分布 220、221、222 は出力スラブ導波路 207 の収差等の影響を受ける。光信号 λ_5 の電界分布 221 はモード変換部 203 の電界分布 209 を再現して左右対称の双峰状となるものの、信号 λ_1 、 λ_9 の電界分布 220、221 は左右非対称となる。非対称は、おもに出力スラブ導波路 207 の収差が原因であるため、集光面 219 の H-H' の端に集光する光信号ほど大きくなる。集光面 219 の H-H' において各信号は、各出力導波路 208 に入射・伝搬し、出力端 223 から別々に取り出すことができる。

【0016】図 12 は、従来のアレイ導波路回折格子型光波長分波器の損失波長特性 224、225、226、227 を模式的に示す説明図である。

【0017】図 11 及び図 12 に示すように、各出力導波路 208 の挿入損失は、集光面における光信号の電界分布 220、221、222 と、各出力導波路 208 の固有モードの重畳積分で決定される。光信号の電界分布 220、221、222 が、波長に応じて集光面 219 の H-H' 上を移動する。電界分布形状も、光信号の集光位置が Y_5 近傍から離れるにしたがって非対称となる

which has maximum value and extremely small value with effect of diffraction. In F-F' of incident edge 210 of array waveguide diffraction grating, light signal is divided, the incident * propagation does each channel waveguide 206.

[0012] As shown in Figure 8 (c), each both signal electric field distribution 211 with F-F' of the incident edge 210 reproduction it does electric field distribution 213 in G-G' of terminal 212 of the array waveguide diffraction grating 205.

[0013] As shown in Figure 9 (a), (b) and (c), phase surface 214 of light signal 1 to 9 in G-G' of terminal 212 differs depending upon light signal. Here, from aforementioned Formula (3), phase surface 215 of the light signal 5 becomes as for phase aspect of other light signal, left-right symmetry, the slope which responds to propagation constant vis-a-vis H-H' of the array waveguide diffraction grating terminal 219, causes.

[0014] As shown in Figure 10, phase shift has changed in continuous in channel waveguide 205 of array waveguide diffraction grating 206. Each light signal, in direction which responds to this slope in the output slab waveguide 207, propagation it does. Therefore, each light signal light collection makes respectively point Y_1 to Y_9 (not shown) where the light collection surface 219 of output slab waveguide 207 differs.

[0015] As here, shown in Figure 11, electric field distribution 220, 221, 222 of each signal in H-H' of the light collection surface 219 receives aberration or other influence of output slab waveguide 207. As for electric field distribution 221 of light signal 5 reproduction doing electric field distribution 209 of mode converting part 203, bimodal condition of left-right symmetry and, electric field distribution 220, 221 of signal 1 and 9 becomes left and right asymmetry. Asymmetry, because aberration of output slab waveguide 207 is cause mainly, about light signal which light collection is done becomes large in edge of the H-H' of light collection surface 219. Each signal, incidence and propagation does in each output waveguide 208 in the H-H' of light collection surface 219, it is possible to remove from the output terminal 223 separately.

[0016] Figure 12 is explanatory diagram which shows loss wavelength characteristic 224, 225, 226, 227 of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic.

[0017] Way it shows in Figure 11 and Figure 12, as for insertion loss of each output waveguide 208, it is decided with electric field distribution 220, 221, 222 of light signal in light collection aspect and superimposition integral calculus of peculiar mode of each output waveguide 208. electric field distribution 220, 221, 222 of light signal, moves on H-H' of light collection surface 219 according to wavelength. Also electric field distribution

、集光位置が Y_5 近傍では、電界分布形状221も左右対称に近い。波長がわずかに変動しても、挿入損失はあまり変化しない。しかし、集光位置が Y_1 、 Y_9 近傍では、電界分布形状220、222が左右非対称であるため、波長が変動すると、挿入損失は大きく変動する。したがって、波長 λ_5 の出力導波路208の損失波長特性224は、通過帯域227で平坦な特性となるのに対して、波長 λ_1 及び λ_9 の出力導波路の損失波長特性225、226の通過帯域特性は、傾いた特性とならざるを得なかった。

[0018]

【発明が解決しようとする課題】このように、従来の光波長合分波器によると、出力側スラブ導波路の収差等により、損失波長特性の通過帯域特性が平坦にならないので、光源の波長が変動したとき、挿入損失が大きく変化するという問題があり、必ずしも十分に満足し得るものではなかった。

【0019】従って、本発明の目的は、光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器を提供することにある。

[0020]

【課題を解決するための手段】本発明は、上記目的を達成するため、以下の光波長合分波器を提供するものである。

【0021】[1] 基板上に、1本以上の入力用チャネル導波路と、1本以上の出力用チャネル導波路と、導波路長を最短なものから最長なものへ所定の長さずつ順次長く設定した複数本のチャネル導波路で構成したアレイ導波路回折格子と、前記入力用チャネル導波路及びアレイ導波路回折格子を接続する扇形の入力側スラブ導波路と、前記出力用チャネル導波路及び前記アレイ導波路回折格子を接続する扇形の出力側スラブ導波路とを備えた光波長合分波器であって、前記入力側スラブ導波路及び前記アレイ導波路回折格子の接続部、又は前記出力側スラブ導波路及び前記アレイ導波路回折格子の接続部のうちの少なくとも一方において、アレイ導波路格子を構成する各チャネル導波路の中心軸と、それぞれ隣接するチ

geometry, light collection position of light signal leaves from Y_5 vicinity following, becomes asymmetry. light collection position does not change with Y_5 vicinity, because also electric field distribution geometry 221 is close to left-right symmetry, wavelength fluctuating barely, as for insertion loss arrow excessively. But, light collection position fluctuates with Y_1, Y_9 vicinity, because electric field distribution geometry 220, 222 is the left and right asymmetry, when wavelength fluctuates, as for insertion loss largely. Therefore, as for loss wavelength characteristic 224 of output waveguide 208 of wavelength λ_5 , vis-a-vis becoming planar characteristic with passing domain 227, if as for the passing domain characteristic of loss wavelength characteristic 225, 226 of output waveguide of wavelength λ_1 and the λ_9 , characteristic which tilts strainer was not obtained.

[0018]

[Problems to be Solved by the Invention] This way, according to conventional light wavelength divider/coupler, because passing domain characteristic of the loss wavelength characteristic does not become flat depending upon aberration etc of the output side slab waveguide, when wavelength of light source fluctuated, there was a problem that, insertion loss changes largely, it was not something which always it can be satisfied with fully.

[0019] Therefore, it is to offer light wavelength divider/coupler where combination amount wave of light signal to which as for objective of this invention, loss fluctuation for wavelength fluctuation of light source is small, at the same time stabilizes is possible.

[0020]

[Means to Solve the Problems] This invention, in order to achieve above-mentioned objective, is something which offers light wavelength divider/coupler below.

[0021] [1] To on substrate, channel waveguide for input of one or more, channel waveguide for output of one or more, waveguide length shortest from thing longest to thing at a time the specified length sequential is formed with multiple channel waveguide which is set long the array waveguide diffraction grating which, channel waveguide for front entry power and connects array waveguide diffraction grating input side slab waveguide of the fan shape which, Being a light wavelength divider/coupler which has with channel waveguide for aforementioned output and output side slab waveguide of fan shape which connects aforementioned array waveguide diffraction grating being. Changing gradually connector of aforementioned input side slab waveguide and

チャンネル導波路の中心軸との間隔を、全チャンネル導波路にわたって徐々に変化させてなることを特徴とする光波長合分波器。

【0022】 [2] 前記入力側スラブ導波路の前記接続部及び前記出力側スラブ導波路の前記接続部において、前記アレイ導波路回折格子を構成する前記チャンネル導波路を、前記入力スラブ導波路及び前記出力側スラブ導波路に沿ってそれぞれ放射状に配置し、前記各チャンネル導波路の中心軸と、それぞれ隣接するチャンネル導波路の中心軸との間の所定の基準点に対する角度を、全チャンネル導波路にわたって徐々に変化させてなる前記 [1] に記載の光波長合分波器。

【0023】 [3] 前記アレイ導波路回折格子を構成する前記チャンネル導波路の本数を N 、前記各チャンネル導波路の番号を i 、予め定めた基準のチャンネル導波路の番号 j としたとき、前記入力側スラブ導波路又は前記出力側スラブ導波路の前記接続部における第 i 番目の前記チャンネル導波路と第 $i + 1$ 番目の前記チャンネル導波路との間の前記所定の基準点に対する角度 $\Delta \theta_i$ を、下記式 (1) に示すように、徐々に変化させてなる前記 [2] に記載の光波長合分波器。

$$\Delta \theta_i = \Delta \theta_j \cdot \{1 + \sum A_k \cdot |i - j|^k\} \quad \dots (1)$$

(式 (1) 中、 A_k は定数であり、 k は 1 ~ N の整数である。)

【0024】 [4] 前記式 (1) において、所定の定数 A の範囲を $-0.001 \leq A_k \leq 0.001$ (k は 1 ~ N の整数である) とした前記 [3] に記載の光波長合分波器。

【0025】 [5] 前記式 (1) において、前記アレイ導波路回折格子を構成するチャンネル導波路の本数 (N) を 1 とすることにより、前記角度 $\Delta \theta_i$ を下記式 (2) に示すものとした前記 [3] 又は [4] に記載の光波長合分波器。

$$\Delta \theta_i = \Delta \theta_j \cdot \{1 + A_1 \cdot |i - j|\} \quad \dots (2)$$

the aforementioned array waveguide diffraction grating, in at least one among connector of aforementioned output side slab waveguide and aforementioned array waveguide diffraction grating, spacing of the center axis of channel waveguide which is adjacent with center axis of each channel waveguide which forms array waveguide grating, respectively, over all channel waveguide, light wavelength divider/coupler which designates that it becomes as feature.

[0022] [2] In aforementioned connector of aforementioned input side slab waveguide and aforementioned connector of aforementioned output side slab waveguide putting, aforementioned channel waveguide which forms aforementioned array waveguide diffraction grating, changing gradually angle for specified reference point with center axis of channel waveguide which arranges respectively in radial alongside front entry power slab waveguide, and aforementioned output side slab waveguide is adjacent with center axis of aforementioned each channel waveguide, respectively, over all channel waveguide, the light wavelength divider/coupler which it states in aforementioned [1] which becomes.

[0023] [3] Number of aforementioned channel waveguide which forms aforementioned array waveguide diffraction grating N , When number of aforementioned each channel waveguide i , making the number j of channel waveguide of standard which is decided beforehand, as shown the angle i for aforementioned specified reference point with aforementioned channel waveguide of i 'th in aforementioned input side slab waveguide or aforementioned connector of aforementioned output side slab waveguide and aforementioned channel waveguide of i 'th + first, in below-mentioned Formula (1), changing gradually, light wavelength divider/coupler which it states in aforementioned [2] which becomes.

$$i = j \cdot \{1 + A_k \cdot |i - j|^k\} \quad \dots (1)$$

(Formula (1) In, A_k is constant, k is integer of 1 to N .)

[0024] [4] In aforementioned Formula (1), range of specified constant A - 0.001 A_k 0.001 (k is integer of 1 to N .) with the light wavelength divider/coupler which is stated in aforementioned [3] which is done.

[0025] [5] Light wavelength divider/coupler which is stated in aforementioned [3] or [4] show aforementioned angle i in below-mentioned Formula (2) in the aforementioned Formula (1), by designating number (N) of channel waveguide which forms aforementioned array waveguide diffraction grating as 1.

$$i = j \cdot \{1 + A_1 \cdot |i - j|\} \quad \dots (2)$$

(2)

(式(2)中、 A_1 は定数であり、 $A_1 \neq 0$ である。)

[0026]

【発明の実施の形態】以下、本発明の実施の形態を、図面を参照しつつ具体的に説明する。図1は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器を模式的に示す説明図であり、図1(a)は、その全体図で、図1(b)は、アレイ導波路回折格子部の拡大図である。ここでは、一例として、9つの光信号 $\lambda_1 \sim \lambda_9$ ($\lambda_1 < \lambda_2 < \dots < \lambda_8 < \lambda_9$)を合分波するための光波長合分波器を示す。

【0027】図1(a)に示すように、基板101上に、入力導波路102と、入力側スラブ導波路104と、最短なものから最長なものへ前記式(3)に示す ΔL の長さずつ順次長く設定したN本のチャンネル導波路105で構成されたアレイ導波路回折格子106と、出力側スラブ導波路107と、9本の出力導波路108とから形成されている。また、入力導波路102と入力側スラブ導波路104の接続部には、損失波長特性の通過域特性を平坦化するためのモード変換部103を形成している。

【0028】図1(b)に示すように、アレイ導波路回折格子106を構成する各チャンネル導波路105は、入力スラブ導波路104の接続部及び出力導波路107の接続部において、入力スラブ導波路104及び出力スラブ導波路107の基準点109、110に対して放射状に配置している。各チャンネル導波路105がそれぞれの隣接するチャンネル導波路となす角度 $\Delta\theta$ は、アレイ導波路回折格子の下側(B、C側)から上側(B、C側)に向かって徐々に変化している。ここで、アレイ導波路回折格子106の第iチャンネル導波路が、隣接する第i+1チャンネル導波路となす角度 $\Delta\theta_{i+1}$ は、基準となる第jチャンネル導波路及びその角度間隔 $\Delta\theta_{j+1}$ に対して、下記式(4)となるように配置している。

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + A \cdot |i - j|\} \quad \dots (4)$$

(式(4)中、iはアレイ導波路格子を構成するチャンネル導波路の番号、jは基準導波路番号、Aは定数で、 $A \neq 0$ である。)

(Formula (2) In. A_1 is constant, is $A_1 \neq 0$.)

[0026]

[Embodiment of Invention] While below, embodiment of this invention, referring to drawing, you explain concretely. Figure 1 is explanatory diagram which shows array waveguide diffraction grating type light wavelength divider/coupler which is one embodiment of light wavelength divider/coupler of this invention in schematic as for Figure 1 (a), with the whole diagram as for Figure 1 (b), is expanded view of array waveguide diffraction grating section. Here, 9 horn light signal 1 to 9 ($1 < 2 < \dots < 8 < 9$) light wavelength divider/coupler in order combination amount wave to do is shown as one example.

[0027] As shown in Figure 1 (a), on substrate 101, input waveguide 102 and input side slab waveguide 104 and the shortest from thing longest to thing each length of the L which is shown in aforementioned Formula (3) it is formed from the output waveguide 108 of array waveguide diffraction grating 106 and output side slab waveguide 107 and 9 book which are formed with channel waveguide 105 of N book which sequential long sets. In addition, mode converting part 103 in order planarization to do passing limit characteristic of loss wavelength characteristic, to input waveguide 102 and connector of input side slab waveguide 104 is formed.

[0028] As shown in Figure 1 (b), it arranges each channel waveguide 105 which forms array waveguide diffraction grating 106, in radial in connector of input slab waveguide 104 and connector of output waveguide 107, vis-a-vis reference point 109, 110 of input slab waveguide 104 and the output slab waveguide 107. channel waveguide where each channel waveguide 105 is adjacent each one angle which is formed has changed gradually from underside (B, C side) of array waveguide diffraction grating facing toward topside (B, C side). Here, i'th channel waveguide of array waveguide diffraction grating 106, in order to become the below-mentioned Formula (4) vis-a-vis j channel waveguide and its angle spacing $\Delta\theta_{j+1}$ which become the standard, has arranged angle $\Delta\theta_{i+1}$ which i'th + 1 channel waveguide which is adjacent forms.

$$i = j \cdot \{1 + A \cdot |i - j|\} \quad \dots (4)$$

(Formula (4) In, as for i number of channel waveguide which forms array waveguide grating, as for j as for reference waveguide number and A with constant, it is $A \neq 0$.)

[0029] 本発明では、アレイ導波路回折格子106を構成するチャンネル導波路105の本数を60本、所定の導波路番号jを30、この第30チャンネル導波路と第31チャンネル導波路とがなす角度間隔 $\Delta\theta_{30}$ を0.2(deg.)とし、定数Aを0.0002とした。なお、この定数Aは、前記式(1)に示すように、値の絶対値が小さいと補正の効果が弱く、逆に大きすぎると補正の効果が強すぎるため、-0.001から0.001の範囲とすることが好ましい。

[0030] 図2は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における電界分布を模式的に示す説明図であり、図2(a)は、光信号のモード変換部103のA-A'での電界分布113、図2(b)は、アレイ導波路回折格子入射端114のB-B'での電界分布115、図2(c)は、アレイ導波路回折格子出射端116のC-C'での電界分布117をそれぞれ示す。

[0031] 図3は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布を模式的に示す説明図であり、図3(a)は、アレイ導波路回折格子入射端114のB-B'における光信号 λ_1 、 λ_9 の位相分布118、図3(b)は、アレイ導波路回折格子出射端116における光信号 λ_1 、 λ_9 の位相分布119をそれぞれ示す。

[0032] 図4は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相差を模式的に示す説明図であり、図4(a)は、光信号 λ_1 と λ_5 との位相差120、図4(b)、(c)、(d)は、光信号 λ_3 、 λ_7 、 λ_9 と、 λ_5 との位相差121、122、123をそれぞれ示す。

[0033] 図5は、本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の集光面124における光信号 λ_1 、 λ_3 、 λ_5 、 λ_7 、 λ_9 の電界分布125、126、127、128、129をそれぞれ示す。ここで、アレイ導波路回折格子106の隣接チャンネル導波路の導波路長さ ΔL は、前記式(3)を満足するように設計している。

[0029] With this invention, number of channel waveguide 105 which forms array waveguide diffraction grating 106 60 and specified waveguide number j 30, this 3rd 0 channel waveguide and angle interval 30 which 3rd 1 channel waveguide forms were designated as 0.2(deg.), constant A was designated as the 0.0002. Furthermore, when as for this constant A, as shown in the aforementioned Formula (1), when absolute value of value is small, effect of the correction is weak, is too large conversely because effect of correction is too strong, it is desirable to make range of -0.001 to 0.001.

[0030] As for Figure 2, it is an explanatory diagram which shows electric field distribution in specified site of the array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of this invention in the schematic, as for Figure 2(a), electric field distribution 113 with A-A' of mode converting part 103 of the light signal, as for Figure 2(b), electric field distribution 115 with B-B' of array waveguide diffraction grating incident edge 114, as for the Figure 2(c), electric field distribution 117 with C-C' of array waveguide diffraction grating emitting end 116 is shown respectively.

[0031] As for Figure 3, it is an explanatory diagram which shows phase distribution of light signal in the specified site of array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of the this invention in schematic, as for Figure 3(a), phase distribution 118 of light signal 1 and the 9 in B-B' of array waveguide diffraction grating incident edge 114, as for Figure 3(b), phase distribution 119 of the light signal 1 and 9 in 116 is shown respectively.

[0032] As for Figure 4, it is an explanatory diagram which shows phase shift of light signal in the specified site of array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of the this invention in schematic, as for Figure 4(a), phase shift 120 of light signal 1 and the 5, as for Figure 4(b), (c) and (d), phase shift 121, 122, 123 of light signal 3, 7, the 9 and 5 is shown respectively.

[0033] As for Figure 5, electric field distribution 125, 126, 127, 128, 129 of light signal 1, 3, 5, the 7 and 9 in light collection surface 124 of array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of this invention is shown respectively. Here, in order to satisfy aforementioned Formula (3), you design the waveguide long difference ΔL of adjacent channel waveguide of array waveguide diffraction grating 106.

[0034] 以下、図1を用い、かつ適宜他図を参照して、本発明の光波長合分波器の作用を説明する。

[0035] 光信号 $\lambda_1 \sim \lambda_9$ は、入力導波路102、モード変換部103、入力スラブ導波路104、アレイ導波路回折格子106、出力スラブ導波路107、出力導波路108の順で伝搬する。まず、入力導波路102からアレイ導波路入射端114までの伝搬について説明する。

[0036] 図1(a)に示すように、入射端130から入射された光信号 $\lambda_1 \sim \lambda_9$ は、入力導波路102からモード変換部103へと伝搬する。光信号 $\lambda_1 \sim \lambda_9$ はモード変換部103のA-A'で、双峰状の電界分布113に変形される。

[0037] 図1(b)に示すように、光信号 $\lambda_1 \sim \lambda_9$ は入力スラブ導波路104において回折の効果により広げられ、図2(b)に示すように、アレイ導波路回折格子入射端114のB-B'では、極大値、極小値をもつ分布115となる。

[0038] 図3(a)に示すように、位相分布118は、モード変換部103において電界分布を双峰状にしたことにより、一部に π だけずれた分布129を持つ形状となる。

[0039] 次に、アレイ導波路回折格子106から出力導波路108までの光信号の様子について説明する。なお、この部分では光信号の波長によって伝搬の様子が異なるため、まず前記式(3)を満足する λ_5 について説明し、次にその他の光信号について説明する。

[0040] 図1(b)に示すように、光信号 λ_5 はアレイ導波路回折格子入射端114のB-B'において、各チャネル導波路106に入射・分割され、それぞれのチャネル導波路内を伝搬する。アレイ導波路回折格子終端116のC-C'では再び一つに収束する。

[0041] 図2(c)に示すように、電界分布117は、入射端114のB-B'での電界分布115とほぼ同じ形状となる。図3(b)に示す位相分布119については、光信号 λ_5 が前記式(3)を満足するため、アレイ導波路回折格子伝搬前と全く同じように左右対称で一部に π だけ位相のずれた分布になる。したがって、図1(b)に示すように、光信号 λ_5 は出力スラブ導波路107上の基準点110に焦点を結ぶ。

[0034] Below, making use of Figure 1, at same time referring to as needed other figure, you explain action of light wavelength divider/coupler of this invention.

[0035] Light signal 1 to 9, input waveguide 102, mode converting part 103 and input slab waveguide 104, array waveguide diffraction grating 106 and output slab waveguide 107, propagation does in order of output waveguide 108. First, you explain from input waveguide 102 concerning propagation to the array waveguide incident edge 114.

[0036] As shown in Figure 1 (a), from incident edge 130 light signal 1 to 9 which incidence is done from input waveguide 102 propagation does to mode converting part 103. Light signal 1 to 9 with A-A' of mode converting part 103, becomes deformed in electric field distribution 113 of bimodal condition.

[0037] As shown in Figure 1 (b), light signal 1 to 9 is expanded by effect of the diffraction in input slab waveguide 104, as shown in Figure 2(b), with B-B' of the array waveguide diffraction grating incident edge 114, becomes distribution 115 which has maximum value and the extremely small value.

[0038] As shown in Figure 3 (a), phase distribution 118 is in part by designating the electric field distribution as bimodal condition in mode converting part 103, and it becomes geometry which has distribution 129 which can be shaved.

[0039] Next, you explain concerning circumstances of light signal to the output waveguide 108 from array waveguide diffraction grating 106. Furthermore, because with this portion circumstances of the propagation differ depending upon wavelength of light signal, you explain concerning 5 which first satisfies aforementioned Formula (3), next you explain concerning other light signal.

[0040] As shown in Figure 1 (b), light signal 5 incident * is divided by each channel waveguide 106 in B-B' of array waveguide diffraction grating incident edge 114, propagation does inside respective channel waveguide. With C-C' of array waveguide diffraction grating terminal 116 it focuses again in one.

[0041] As shown in Figure 2 (c), electric field distribution 117 electric field distribution 115 with B-B' of incident edge 114 and almost becomes same shape. Because light signal 5 satisfies aforementioned Formula (3) concerning the phase distribution 119 which is shown in Figure 3 (b), completely in same way as before array waveguide diffraction grating propagation with left-right symmetry in part just it becomes the distribution to which phase slips. Therefore, as shown in

【0042】図5に示すように、その電界分布127は、図2(a)に示すモード変換部103での電界分布113とほぼ同形状となる。さらに、図1(b)に示すように、光信号 λ_5 は基準点110に接続された出力導波路を伝搬し、出力端から出射される。

【0043】以下、 λ_5 以外の光信号について説明する。ここでは、例として光信号 λ_1 、 λ_3 、 λ_7 、 λ_9 の場合について説明する。図1に示すように、光信号 λ_1 、 λ_3 、 λ_7 、 λ_9 もそれぞれアレイ導波路回折格子106で分割され、それぞれチャネル導波路105を伝搬する。アレイ導波路回折格子106伝搬後の電界分布は、光信号 λ_5 の場合とほぼ同じである。

【0044】ただし、図4(a)、(b)、(c)、(d)に示すように、位相分布については、曲線状で、かつ全体的に傾斜している、曲線の度合い及び傾きは光信号 λ_5 との波長の差が大きくなるほど大きくなっている。位相差が全体的に傾斜しているのは、伝搬定数 β が波長分散を持つためであり、この傾きによって集光位置が異なっている。位相差が曲線状になるのはアレイ導波路回折格子106を構成するチャネル導波路105の間隔が前記式(4)に示したように全体的に変化しているためであり、出力スラブ導波路等における収差を相殺する効果を持つ。

【0045】したがって、各光信号は、出力スラブ導波路107の集光面124のD-D'上の点 $X_1 \sim X_9$ (図示せず)にそれぞれ集光し、その電界分布125、126、128、129も収差が相殺され、各光信号とも左右対称の双峰状となる。さらに、各信号は各出力導波路108に入射、伝搬し、出力端131から別々に取り出すことができる。

【0046】図6は、本発明の光波長合成分波器の一実施の形態であるアレイ導波路回折格子型光波長合成分波器の損失波長特性132を模式的に示す説明図である。

【0047】図5及び図6に示すように、各出力導波路108の挿入損失は、集光面124のC-C'における光信号の電界分布125、126、127、128、129と、各出力導波路108の固有モードの重畳積分で

Figure 1 (b), light signal 5 ties focus to thereference point 110 on output slab waveguide 107.

[0042] As shown in Figure 5, electric field distribution 127 electric field distribution 113 with mode converting part 103 which is shown in Figure 2(a) and almost becomes same geometry. Furthermore, as shown in Figure 1 (b), light signal 5 propagation does the output waveguide which is connected to reference point 110, radiation is done from the output terminal.

[0043] You explain concerning light signal below and other than 5. Here, as example in case of light signal 1, 3, 7 and the 9 being attached, you explain. As shown in Figure 1, also light signal 1, 3, 7 and the 9 are divided respectively with array waveguide diffraction grating 106, propagation do the respective channel waveguide 105. electric field distribution after array waveguide diffraction grating 106 propagation is almost same as case of light signal 5.

[0044] However, as Figure 4 (a), (b), (c), shown in (d), with curve shape, at the same time it is inclined to entire concerning phase distribution, extent and slope of curve extent where difference of wavelength of the light signal 5 becomes large have become large. Fact that phase shift is inclined to entire, is, because the propagation constant has wavelength dispersion, light collection position differs depending upon this slope. Fact that phase shift becomes curve shape as spacing of channel waveguide 105 which forms array waveguide diffraction grating 106 shows in aforementioned Formula (4), is, because it has changed in entire, has effect which offsets aberration in the output slab waveguide etc.

[0045] Therefore, each light signal light collection makes respectively point X_1 to X_9 (not shown) on the D-D' of light collection surface 124 of output slab waveguide 107, aberration is offset also electric field distribution 125, 126, 128, 129, also each light signal becomes bimodal condition of the left-right symmetry. Furthermore, each signal incidence and propagation does in each output waveguide 108, it is possible to remove from output terminal 131 separately.

[0046] Figure 6 is explanatory diagram which shows loss wavelength characteristic 132 of array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in schematic.

[0047] Way it shows in Figure 5 and Figure 6, as for insertion loss of each output waveguide 108, it is decided with electric field distribution 125, 126, 127, 128, 129 of light signal in C-C' of light collection surface 124 and superposition integral calculus

決定される。光信号の電界分布 125、126、127、128、129が、波長に応じて集光面 124 の D-D' 上を、双峰状の形状を保ったまま移動する。そのため、光信号の波長がわずかに変動しても、挿入損失はあまり変化しない。つまり、図 6 に示すように損失波長特性 132 は、各光信号の波長 $\lambda_1 \sim \lambda_9$ に通過帯域 133 内の波長変動が生じても通過帯域 133 が平坦かつ左右対称であるため、挿入損失は増加しない。

【0048】なお、本発明の光波長合分波器に用いられる基板としては、例えば、ガラス基板だけでなく半導体基板等にも形成することができる。また、基板 101 上に形成されるコア、クラッド、バッファ層についても、ガラス系の材料だけでなく半導体材料など、光学的に透明な材料を用いて形成することも可能である。

【0049】

【発明の効果】以上説明した通り、本発明の光波長合分波器によると、入力スラブ導波路及び出力スラブ導波路におけるアレイ導波路回折格子の各チャンネル導波路の配置角度を最適化することで、出力スラブ導波路における収差等を相殺し、全出力導波路において、平坦な通過域特性を実現できるので、光源の波長変動に対する損失変動が小さく、かつ安定した光信号の合分波が可能な光波長合分波器を提供することができる。

【0050】

【図面の簡単な説明】

【図 1】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器を模式的に示す説明図であり、図 1 (a) は、その全体図で、図 1 (b) は、アレイ導波路回折格子部の拡大図である。

【図 2】本発明の光波長合分波器の一実施の形態であるアレイ導波路回折格子型光波長合分波器の所定部位における電界分布を模式的に示す説明図であり、図 2 (a) は、光信号のモード変換部 103 の A-A' での電界分布 113、図 2 (b) は、アレイ導波路回折格子入射端 114 の B-B' での電界分布 115、図 2 (c) は、アレイ導波路回折格子出射端 116 の C-C' での電界分布 117 をそれぞれ示す。

of peculiar mode of each output waveguide 108, electric field distribution 125, 126, 127, 128, 129 of light signal, on D-D' of light collection surface 124, while the geometry of binodal condition is maintained moves according to the wavelength. Because of that, wavelength of light signal fluctuating barely, insertion loss does not change excessively. In other words, as shown in Figure 6, as for loss wavelength characteristic 132, wavelength fluctuation inside passing domain 133 occurring in wavelength 1 to 9 of each light signal, because passing domain 133 is flat and left-right symmetry, as for the insertion loss it does not increase.

[0048] Furthermore, it can form even in semiconductor substrate etc not only a for example glass substrate as the substrate which is used for light wavelength divider/coupler of this invention. In addition, concerning core, cladding and buffer layer which are formed on substrate 101, not only a material of glass type forming making use of, optically transparent material such as semiconductor material it is possible.

[0049]

[Effects of the Invention] Above you explained sort, According to light wavelength divider/coupler of this invention, Input slab waveguide and positioning angle of each channel waveguide of array waveguide diffraction grating in output slab waveguide optimization do with, To offset aberration etc in output slab waveguide, because planar passing limits characteristic can be actualized in full power waveguide, light wavelength divider/coupler where combination amount wave of light signal to which loss fluctuation for wavelength fluctuation of light source is small, at the same time stabilizes is possible can be offered.

[0050]

[Brief Explanation of the Drawing(s)]

[Figure 1] It is an explanatory diagram which shows array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of the light wavelength divider/coupler of this invention in schematic as for Figure 1 (a), with whole diagram, as for Figure 1 (b), is an expanded view of array waveguide diffraction grating section.

[Figure 2] It is an explanatory diagram which shows electric field distribution in specified site of array waveguide diffraction grating type light wavelength divider/coupler which is a one embodiment of light wavelength divider/coupler of this invention in schematic, as for the Figure 2(a), electric field distribution 113 with A-A' of mode converting part 103 of light signal, as for the Figure 2(b), electric field distribution 115 with B-B' of array waveguide diffraction grating incident edge

【図3】本発明の光波長合分波器の一実施の形態であるアレイド導波路回折格子型光波長合分波器の所定部位における光信号の位相分布を模式的に示す説明図であり、図3(a)は、アレイド導波路回折格子入射端114のB-B'における光信号 λ_1 、 λ_9 の位相分布118、図3(b)は、アレイド導波路回折格子出射端116における光信号 λ_1 、 λ_9 の位相分布119をそれぞれ示す。

【図4】本発明の光波長合分波器の一実施の形態であるアレイド導波路回折格子型光波長合分波器の所定部位における光信号の位相差を模式的に示す説明図であり、図4(a)は、光信号 λ_1 と λ_5 との位相差120、図4(b)、(c)、(d)は、光信号 λ_3 、 λ_7 、 λ_9 と、 λ_5 との位相差121、122、123をそれぞれ示す。

【図5】本発明の光波長合分波器の一実施の形態であるアレイド導波路回折格子型光波長合分波器の集光面124における光信号 λ_1 、 λ_3 、 λ_5 、 λ_7 、 λ_9 の電界分布125、126、127、128、129をそれぞれ示す。

【図6】本発明の光波長合分波器の一実施の形態であるアレイド導波路回折格子型光波長合分波器の損失波長特性132を模式的に示す説明図である。

【図7】従来のアレイド導波路回折格子型光波長合分波器を模式的に示す説明図である。

【図8】従来のアレイド導波路回折格子型光波長合分波器の所定部位における光信号の電界分布を模式的に示す説明図であり、図8(a)は、モード変換部203のE-E'における光信号の電界分布209、図8(b)は、アレイド導波路回折格子入射端210のF-F'における電界分布211、図8(c)は、アレイド導波路回折格子出射端212のG-G'での電界分布213をそれぞれ示す。

【図9】従来のアレイド導波路回折格子型光波長合分波器

114, as for Figure 2(c), the electric field distribution 117 with C-C' of array waveguide diffraction grating emitting end 116 is shown respectively.

[Figure 3] It is an explanatory diagram which shows phase distribution of light signal in specified site of the array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of this invention in the schematic, as for Figure 3(a), phase distribution 118 of light signal 1 and 9 in the B-B' of array waveguide diffraction grating incident edge 114, as for Figure 3(b), phase distribution 119 of light signal 1 and the 9 in array waveguide diffraction grating emitting end 116 is shown respectively.

[Figure 4] It is an explanatory diagram which shows phase shift of light signal in specified site of the array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of this invention in the schematic, as for Figure 4(a), phase shift 120 of light signal 1 and 5, as for the Figure 4(b), (c) and (d), phase shift 121, 122, 123 of light signal 3, 7, 9 and the 5 is shown respectively.

[Figure 5] Electric field distribution 125, 126, 127, 128, 129 of light signal 1, 3, 5, 7 and 9 in light collection surface 124 of array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of the light wavelength divider/coupler of this invention is shown respectively.

[Figure 6] It is an explanatory diagram which shows loss wavelength characteristic 132 of array waveguide diffraction grating type light wavelength divider/coupler which is an embodiment of light wavelength divider/coupler of this invention in schematic.

[Figure 7] It is an explanatory diagram which shows conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic.

[Figure 8] It is an explanatory diagram which shows electric field distribution of light signal in specified site of the conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, as for Figure 8(a), electric field distribution 209 of the light signal in E-E' of mode converting part 203, as for Figure 8(b), electric field distribution 211 and the Figure 8(c) in F-F' of array waveguide diffraction grating incident edge 210 show electric field distribution 213 with G-G' of the array waveguide diffraction grating emitting end 212 respectively.

[Figure 9] It is an explanatory diagram which shows phase distribu

の所定部位における光信号の位相分布を模式的に示す説明図であり、図9(a)、図9(e)、図9(f)は、アレイ導波路回折格子出射端212のG-G'での光信号 λ_1 、 λ_5 、 λ_9 のそれぞれの位相分布214、215、216を示す。

【図10】従来のアレイ導波路回折格子型光波長合分波器の所定部位における光信号の位相分布の差を模式的に示す説明図であり、図10(a)及び図10(b)は、光信号 λ_1 、 λ_9 の位相面214、216と λ_5 の位相面215とのそれぞれの位相分布の差217、218を示す。

【図11】従来のアレイ導波路回折格子型光波長合分波器の集光面219のH-H'における光信号 λ_1 、 λ_5 、 λ_9 の電界分布220、221、222を模式的に示す説明図である。

【図12】従来のアレイ導波路回折格子型光波長合分波器の損失波長特性224、225、226、227を模式的に示す説明図である。

【符号の説明】

- 101: 基板
- 102: 入力用導波路
- 103: モード変換部
- 104: 入力スラブ導波路
- 105: チャンネル導波路
- 106: アレイ導波路回折格子
- 107: 出力側スラブ導波路
- 108: 出力用導波路
- 109: 基準点
- 110: 基準点
- 111: 第iチャンネル導波路が第i+1チャンネル導波路となす角度
- 112: 所定の第jチャンネル導波路が第j+1チャンネル導波路となす角度

tion of light signal in specified site of the conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, Figure 9(a), Figure 9(e) and Figure 9(f), the light signal λ_1 with G-G' of array waveguide diffraction grating emitting end 212, show respective phase distribution 214, 215, 216 of the λ_1 and λ_9 .

[Figure 10] It is an explanatory diagram which shows difference of phase distribution of light signal in the specified site of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic, Figure 10(a) and the Figure 10(b), show difference 217, 218 of respective phase distribution of phase surface 214, 216 of light signal λ_1 and λ_9 and phase surface 215 of λ_5 .

[Figure 11] It is an explanatory diagram which shows electric field distribution 220, 221, 222 of light signal λ_1 , λ_5 and the λ_9 in H-H' of light collection surface 219 of conventional array waveguide diffraction grating type light wavelength divider/coupler in schematic.

[Figure 12] It is an explanatory diagram which shows loss wavelength characteristic 224, 225, 226, 227 of conventional array waveguide diffraction grating type light wavelength divider/coupler in the schematic.

[Explanation of Reference Signs in Drawings]

- 101: Substrate
- 102: Waveguide for input
- 103: Mode converting part
- 104: Input slab waveguide
- 105: Channel waveguide
- 106: Array waveguide diffraction grating
- 107: Output side slab waveguide
- 108: Waveguide for output
- 109: Reference point
- 110: Reference point
- 111: I'th channel waveguide forms i'th + 1 channel waveguide angle
- 112: Specified j channel waveguide forms j + 1 channel waveguide angle

113: モード変換部における光信号の電界分布

114: アレイ導波路回折格子入射端

115: アレイ導波路回折格子入射端における光信号の電界分布

116: アレイ導波路回折格子出射端

117: アレイ導波路回折格子出射端における光信号の電界分布

118: アレイ導波路回折格子入射端における光信号 $\lambda_1 \sim \lambda_9$ の位相分布

119: アレイ導波路回折格子出射端における光信号 λ_5 の位相分布

120: アレイ導波路回折格子出射端における光信号 λ_1 の位相分布と光信号 λ_5 の位相分布との差

121: アレイ導波路回折格子出射端における光信号 λ_3 の位相分布と光信号 λ_5 の位相分布との差

122: アレイ導波路回折格子出射端における光信号 λ_7 の位相分布と光信号 λ_5 の位相分布との差

123: アレイ導波路回折格子出射端における光信号 λ_9 の位相分布と光信号 λ_5 の位相分布との差

124: 集光面

125: 集光面における光信号 λ_1 の電界分布

126: 集光面における光信号 λ_3 の電界分布

127: 集光面における光信号 λ_5 の電界分布

128: 集光面における光信号 λ_7 の電界分布

129: 集光面における光信号 λ_9 の電界分布

130: 光信号 λ_5 の焦点位置

131: 焦点位置

132: 出力端

133: 通過域

201: 基板

113: In mode converting part electric field distribution of light signal

114: Array waveguide diffraction grating incident edge

115: In array waveguide diffraction grating incident edge electric field distribution of light signal

116: Array waveguide diffraction grating emitting end

117: In array waveguide diffraction grating emitting end electric field distribution of light signal

118: In array waveguide diffraction grating incident edge phase distribution of light signal 1 to 9

119: In array waveguide diffraction grating emitting end phase distribution of light signal 5

120: Difference of phase distribution of light signal 1 in array waveguide diffraction grating emitting end and phase distribution of the light signal 5

121: Difference of phase distribution of light signal 3 in array waveguide diffraction grating emitting end and phase distribution of the light signal 5

122: Difference of phase distribution of light signal 7 in array waveguide diffraction grating emitting end and phase distribution of the light signal 5

123: Difference of phase distribution of light signal 9 in array waveguide diffraction grating emitting end and phase distribution of the light signal 5

124: Light collection surface

125: In light collection aspect electric field distribution of light signal 1

126: In light collection aspect electric field distribution of light signal 3

127: In light collection aspect electric field distribution of light signal 5

128: In light collection aspect electric field distribution of light signal 7

129: In light collection aspect electric field distribution of light signal 9

130: Focal position of light signal 5

131: Focal position

132: Output terminal

133: Passing limits

201: Substrate

202: 入力用導波路	202: Waveguide for input
203: モード変換部	203: Mode converting part
204: 入力スラブ導波路	204: Input slab waveguide
205: チャネル導波路	205: Channel waveguide
206: アレイ導波路回折格子	206: Array waveguide diffraction grating
207: 出力側スラブ導波路	207: Output side slab waveguide
208: 出力用導波路	208: Waveguide for output
209: ード変換部における光信号の電界分布	209: In - F converting part electric field distribution of light signal
210: アレイ導波路回折格子入射端	210: Array waveguide diffraction grating incident edge
211: アレイ導波路回折格子入射端における光信号の電界分布	211: In array waveguide diffraction grating incident edge electric field distribution of light signal
212: アレイ導波路回折格子出射端	212: Array waveguide diffraction grating emitting end
213: レイ導波路回折格子出射端における光信号の電界分布	213: In ray waveguide diffraction grating emitting end ける electric field distribution of light signal
214: アレイ導波路回折格子出射端における光信号 λ_1 の位相分布	214: In array waveguide diffraction grating emitting end phase distribution of light signal 1
215: アレイ導波路回折格子出射端における光信号 λ_5 の位相分布	215: In array waveguide diffraction grating emitting end phase distribution of light signal 5
216: アレイ導波路回折格子出射端における光信号 λ_9 の位相分布	216: In array waveguide diffraction grating emitting end phase distribution of light signal 9
217: アレイ導波路回折格子出射端における光信号 λ_1 の位相分布と光信号 λ_5 の位相分布との差	217: Difference of phase distribution of light signal 1 in array waveguide diffraction grating emitting end and phase distribution of the light signal 5
218: アレイ導波路回折格子出射端における光信号 λ_9 の位相分布と光信号 λ_5 の位相分布との差	218: Difference of phase distribution of light signal 9 in array waveguide diffraction grating emitting end and phase distribution of the light signal 5
219: 集光面	219: Light collection surface
220: 集光面における光信号 λ_1 の電界分布	220: In light collection aspect electric field distribution of light signal 1
221: 集光面における光信号 λ_5 の電界分布	221: In light collection aspect electric field distribution of light signal 5
222: 集光面における光信号 λ_9 の電界分布	222: In light collection aspect electric field distribution of light signal 9
223: 出力端	223: Output terminal
224: 第5出力導波路の損失波長特性	224: Loss wavelength characteristic of 5th output waveguide

2 2 5 : 第 1 出力導波路の損失波長特性

225: Loss wavelength characteristic of 1st output waveguide

2 2 6 : 第 9 出力導波路の損失波長特性

226: Loss wavelength characteristic of 9th output waveguide

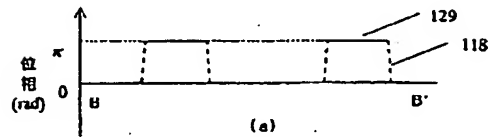
2 2 7 : 通過帯域

227: Passing domain

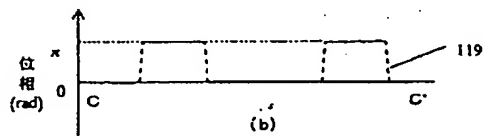
2 2 8 : 第 5 出力導波路

228: 5th output waveguide

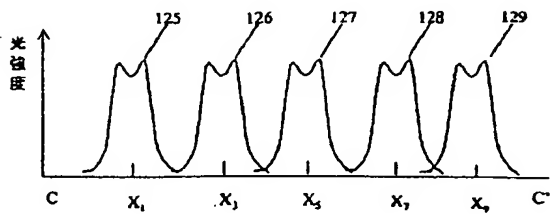
【図 3】



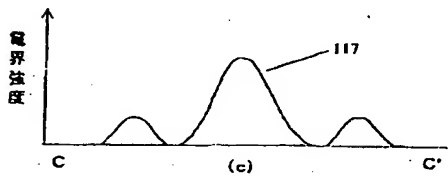
[Figure 3]



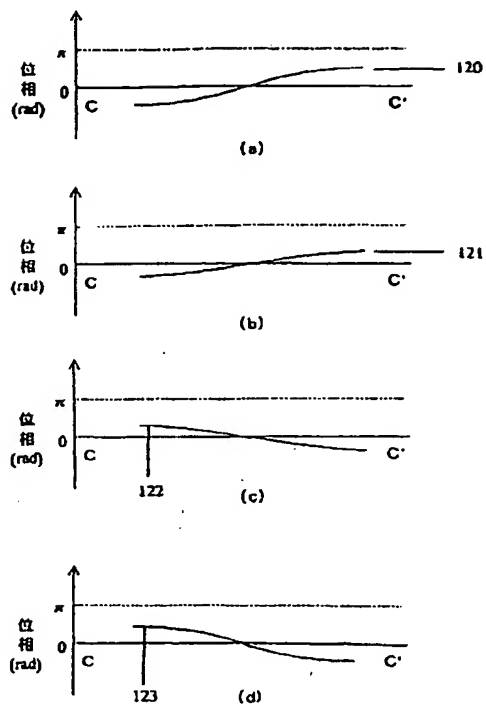
【図 5】



[Figure 5]

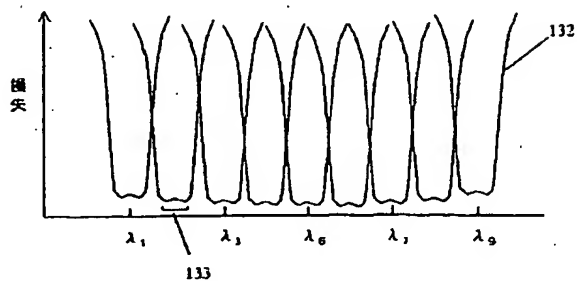
[illegible]

〔图 4〕



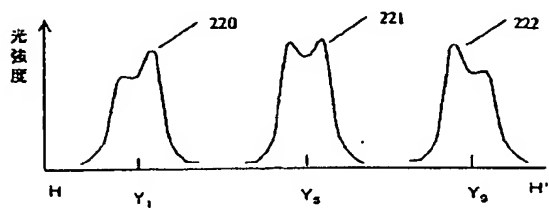
[Figure 4]

〔图 6〕



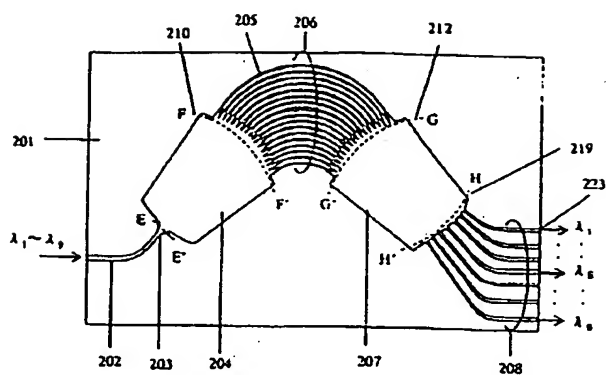
[Figure 6]

〔图 11〕



[Figure 11]

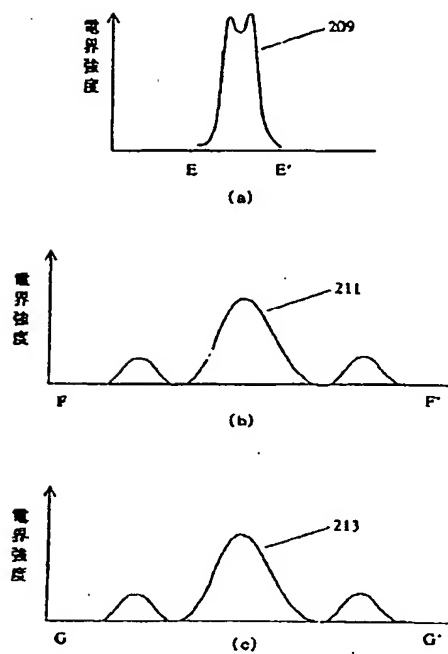
〔図7〕



[Figure 7]

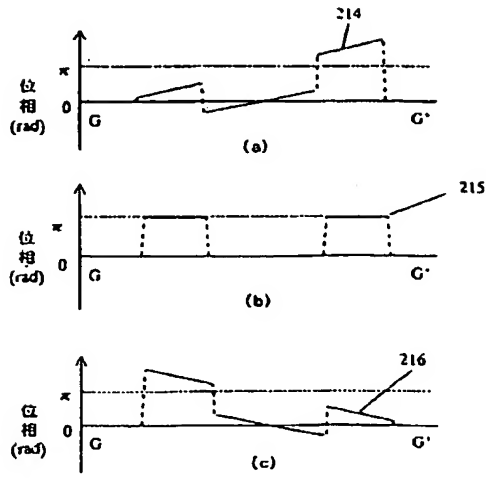
〔図8〕

[Figure 8]



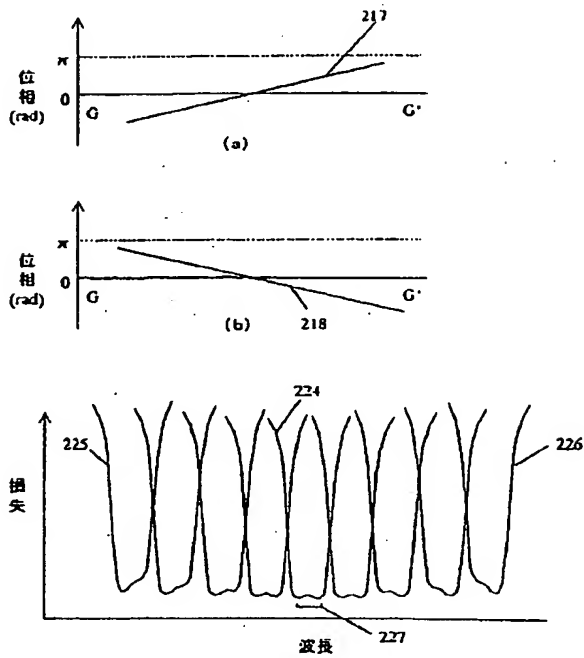
【图9】

[Figure 9]



【图10】

[Figure 10]



【图12】

[Figure 12]

JAPANESE PATENT OFFICE

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Title of the Invention: An Optical Wavelength Multiplexer/Branching Filter

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F terms (reference) 2H047, KA02, KA03, LA01, LA19, LA23.

Abstract (There is an amendment)

Problem To provide an optical wavelength multiplexer/branching filter where there is little loss fluctuation for fluctuations in the wavelength of the light source and stable combination/dividing of optical signals is possible.

Means of Solution It is provided with array waveguide diffraction grating 106 and fan-shaped input side slab waveguide 104, which connects the said input channel waveguide 102 and array waveguide diffraction grating 106, and fan-shaped output side slab waveguide 107, which connects the said output channel waveguides 108 and the said array waveguide diffraction grating 106; in at least 1 out of the connecting section for the said input side slab waveguide 104 and the said array waveguide diffraction grating 106 or the connecting section for the said output side slab waveguide 107 and the said array waveguide diffraction grating 106, the spacing between the central axis of each of the channel waveguides 105, which form array waveguide grating 106, and the central axes of the respective adjacent channel waveguides 105 gradually varies across all the channel waveguides 105.

Scope of Patent Claims

Claim 1 An optical wavelength multiplexer/branching filter characterised in that it is an optical wavelength multiplexer/branching filter which is provided, on a substrate, with 1 or more input channel waveguides and 1 or more output channel waveguides and an array waveguide diffraction grating consisting of a plurality of channel waveguides, in which the waveguide length is sequentially made longer by the requisite length from the shortest to the longest, and a fan-shaped input side slab waveguide, which connects the said input channel waveguide and the array waveguide diffraction grating, and a fan-shaped output side slab waveguide, which connects the said output channel waveguide and the said array waveguide diffraction grating; and in at least 1 out of the connecting section for the said input slab waveguide and the said array waveguide diffraction grating or the connecting section for the said output side waveguide and the said array waveguide diffraction grating the space between the central axis of each of the channel waveguides, which form the said array waveguide grating, and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

Claim 2 The optical wavelength multiplexer/branching filter disclosed in Claim 1 where, in the said connecting section for the said input side slab waveguide and the said connecting section for the said output side slab waveguide, the said channel waveguides that form the said array waveguide diffraction grating are respectively arranged in a radiating shape along the said input side slab waveguide and the said output side slab waveguide; and the angle with respect to the prescribed datum point between the central axis of each of the said channel waveguides and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

Claim 3 The optical wavelength multiplexer/branching filter disclosed in Claim 2 where, if the number of the said channel waveguides forming the said array waveguide diffraction grating is made N, the waveguide number of each of the said channels is made i and the channel waveguide number of the datum established beforehand is made j, the angle $\Delta\theta_i$ with respect to the said prescribed datum point between the channel waveguide that is number i and the one that is i + 1 in the said connecting section of the said input side slab waveguide or the said output side slab waveguide is gradually varied, as shown in equation (1) below.

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + \sum A_k \cdot |i - j| \cdot k\} \dots \dots \dots (1)$$

(In equation (1), A_k is a constant and k is an integer from 1~N.)

Claim 4 The optical wavelength multiplexer/branching filter disclosed in Claim 3 where, in the said equation (1), the range of the prescribed constant A is made to be $-0.001 \leq A_k \leq 0.001$ (k is an integer from 1~N).

Claim 5 The optical wavelength multiplexer/branching filter disclosed in Claims 3 or 4 where, in the said equation (1), by making the number (N) of channel waveguides forming the said array waveguide diffraction grating to be 1, the said angle $\Delta\theta_i$ is made to be the one shown in equation (2) below:

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + A_1 \cdot |i - j| \} \dots \dots \dots (2)$$

(In equation (2), A_1 is a constant and A_1 does not equal 0.)

Detailed Explanation of the Invention

0001

Technical Field to which the Invention Belongs

The present invention relates to an optical wavelength multiplexer/branching filter. In particular, it relates to an optical wavelength multiplexer/branching filter where loss fluctuation for fluctuations in wavelength of the light source are small and stable combining/dividing of optical signals is possible.

0002

Prior Art

The array waveguide diffraction grating is regarded as promising as an optical wavelength multiplexer/branching filter which combines or divides a plurality of optical signals with different wavelengths. Various ones have been proposed (Japanese Patent Publications Hei 4-116607, 4-1634064, 4-220624, 4-326308, 5-157920). In particular, as there is little insertion loss fluctuation for fluctuations in the wavelength of the light source and stable multiplexing and branching of optical signals is possible with an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter where the passing band characteristics have been flattened out, this is looked forward to as a useful device in optical wavelength multiple signals (US Patent 5412744).

0003 Fig.7 is an explanatory diagram showing typically a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Here, as an example, an optical wavelength multiplexer/branching filter is shown for multiplexing and separating the 9 optical signals $\lambda_1 \sim \lambda_9$ ($\lambda_1 < \lambda_2 < \dots < \lambda_8 < \lambda_9$). As show in Fig.7, the conventional optical wavelength multiplexer/branching filter is made up, on a substrate, of input waveguide 202, input side slab waveguide 204, array waveguide diffraction grating 206, which consists of a plurality of channel waveguides 205 with the length of each differing by ΔL , explained later, output slab waveguide 207 and 9 output waveguides 208. Furthermore, mode conversion section 203 has been formed in the connecting section of input waveguide 202 with input slab waveguide 204 in order to level out the pass band characteristics of loss wavelength characteristics.

0004 Fig.8 is an explanatory diagram showing typically the electrical field distribution of the optical signals in a specific region of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.8(a) shows electrical field distribution 209 of the optical signal at E-E' of mode conversion section 203. Fig.8(b) shows the electrical field distribution at F-F' of array waveguide diffraction grating input terminal 210. Fig.8(c) shows the electrical field distribution 213 at G-G' of array waveguide diffraction grating emitting end 212.

0005 Fig.9 is an explanatory diagram showing typically the phase distribution of the optical signals in a specific region of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.9(a), 9(e) [*sic – translator*] and 9(f) [*sic – translator*] show respectively phase distributions 214, 215 and 216 of optical signals λ_1 , λ_3 and λ_9 at G-G' of array waveguide diffraction grating emitting end 212.

0006 Fig.10 is an explanatory diagram showing typically the difference in phase distribution of the optical signals in a specific region of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.10(a) and 10(b) show the respective phase distribution differences 217 and 218 between phase planes 214 and 216 of optical signals λ_1 and λ_9 and phase plane 215 of λ_3 .

0007 Fig.11 is an explanatory diagram showing typically electrical field distributions 220, 221 and 222 of optical signals λ_1 , λ_3 and λ_9 at H-H' of condensing surface 219 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

0008 An explanation will be given below of the action of a conventional optical wavelength multiplexer/branching filter using Fig.7 and making reference to other appropriate diagrams. The

waveguide length difference ΔL between adjacent channel waveguides 205 forming array waveguide diffraction grating 206 has been designed by equation 3 below.

$$\Delta L = 2.m.\pi/\beta(\lambda_s).....(3)$$

(In equation (3), m denotes diffraction degree (a positive integer). $\beta(\lambda_s)$ denotes the channel waveguide propagation constant for optical signal λ_s .)

0009 Optical signals $\lambda_1 \sim \lambda_9$, which are incident from input waveguide 202, are propagated in the order mode conversion section 203, input slab waveguide 204, array waveguide diffraction grating 205, output slab waveguide 207 and output waveguide 208.

0010 As shown in Fig.8(a), the electrical field distribution 209 of the optical signal at E-E' of mode conversion section 203 is a twin peaked shape, symmetrical to left and right.

0011 As shown in Fig.8(b), the electrical field distribution 211 at F-F' at the array waveguide diffraction grating 206 incident end 210 of input slab waveguide 204 is a distribution that has maximum and minimum values as an effect of diffraction. At F-F' at the array waveguide diffraction grating incident end 210 the optical signal is divided and is incident and propagated along each channel waveguide 206.

0012 As shown in Fig.8(c), electrical field distribution 213 at G-G' at end 212 of array waveguide diffraction grating 205 [*sic – translator*] reproduces the electrical field distribution at F-F' of incident end 210 for all the signals.

0013 As shown in Fig.9(a), (b) and (c), phase plane 214 of optical signals $\lambda_1 \sim \lambda_9$ at G-G' of end 212 differs according to the optical signal. Here, from equation (3) above, phase plane 215 of optical signal λ_s becomes symmetrical to right and left. The phase planes of the other optical signals produce a slope with respect to H-H' at array waveguide diffraction grating end 219 according to the propagation constant.

0014 As shown in Fig.10, the phase difference changes continuously in channel waveguides 205 of array waveguide diffraction grating 206. Each optical signal is propagated in a direction corresponding to the slope at output slab waveguide 207. Consequently, the various optical signals respectively condense at different points $Y_1 \sim Y_9$ (not shown in the diagram) of condensing surface 219 of output slab waveguide 207.

0015 Here, as shown in Fig.11, the electrical field distributions 220, 221 and 222 of the respective signals at H-H' of condensing surface 219 are affected by aberrations and suchlike in output slab waveguide 207. Although electrical field distribution 221 of optical signal λ_s reproduces electrical field

distribution 209 of mode conversion section 203 and becomes a twin peak shape that is symmetrical to right and left, electrical field distributions 220 and 221 of signals λ_1 , and λ_9 become asymmetrical to right and left. As the asymmetry is mainly caused by aberrations in output slab waveguide 207, the further the optical signal condenses towards the edge of H-H' of condensing surface 219 the bigger the asymmetry becomes. The various signals at H-H' of condensing surface 219 are incident upon the various output waveguides 208, are propagated and can be extracted separately from output end 223.

0016 Fig. 12 is an explanatory diagram showing typically the loss wavelength characteristics 224, 225, 226 and 227 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

0017 As shown in Fig. 11 and Fig. 12, the insertion losses for each output waveguide 208 are determined by the superimposed integrals of the particular modes of each output waveguide 208 and the electrical field distributions 220, 221 and 222 of the optical signals at the condensing surface. The electrical field distributions 220, 221 and 222 of the optical signals move on H-H' of condensing surface 219 according to the wavelength. The shape of the electrical distribution also becomes more asymmetric as the condensing position of the optical signal goes away from the vicinity of Y_3 . As electrical field distribution shape 221 is close to being symmetrical to right and left with the condensing position in the vicinity of Y_3 , there is not much change in the insertion loss even if the wavelength fluctuates a little. However, as the electrical field distribution shapes 220 and 222 are asymmetric to left and right with condensing positions in the vicinity of Y_1 and Y_9 , the insertion loss fluctuates greatly if the wavelength fluctuates. Consequently, the loss wavelength characteristic 224 of the output waveguide 208 of wavelength λ_5 becomes a flat characteristic in passing band 227. In contrast to this, the passing band characteristics of loss wavelength characteristics 225 and 226 of the output waveguides of wavelengths λ_1 and λ_9 cannot but be tilted characteristics.

0018

Problems to Be Overcome by the Invention

Thus with a conventional optical wavelength multiplexer/branching filter the passing band characteristics of the loss wavelength characteristics do not become flat on account of aberrations and suchlike in the output side slab waveguide and therefore there was the problem that insertion loss changed greatly when the wavelength of the light source fluctuated and this was not always fully satisfactory.

0019 Consequently, the purpose of this invention is to provide an optical wavelength multiplexer/branching filter where loss fluctuation with wavelength fluctuation of the light source is small and stable combining and dividing of optical signals is possible.

0020

Means of Overcoming the Problems

In order to achieve the above aim, this invention is one that provides the following optical wavelength multiplexer/branching filter.

0021 [1] An optical wavelength multiplexer/branching filter characterised in that it is an optical wavelength multiplexer/branching filter which is provided, on a substrate, with 1 or more input channel waveguides and 1 or more output channel waveguides and an array waveguide diffraction grating consisting of a plurality of channel waveguides, in which the waveguide length is sequentially made longer by the requisite length from the shortest to the longest, and a fan-shaped input side slab waveguide, which connects the said input channel waveguide and the array waveguide diffraction grating, and a fan-shaped output side waveguide, which connects the said output channel waveguide and the said array waveguide diffraction grating; and in at least 1 out of the connecting section for the said input slab waveguide and the said array waveguide diffraction grating or the connecting section for the said output side waveguide and the said array waveguide diffraction grating the spacing between the the central axis of each of the channel waveguides, which form the said array waveguide grating, and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

0022 [2] The optical wavelength multiplexer/branching filter disclosed in the said [1] where, in the said connecting section for the said input side slab waveguide and the said connecting section for the said output side slab waveguide, the said channel waveguides that form the said array waveguide diffraction grating are respectively arranged in a radiating shape along the said input side slab waveguide and the said output side slab waveguide; and the angle with respect to the prescribed datum point between the central axis of each of the said channel waveguides and the central axes of the respective adjacent channel waveguides gradually varies across all the channel waveguides.

0023 [3] The optical wavelength multiplexer/branching filter disclosed in the said [2] where, if the number of the said channel waveguides forming the said array waveguide diffraction grating is made N, the waveguide number of each of the said channels is made i and the channel waveguide number of the datum established beforehand is made j, the angle $\Delta\theta_i$ with respect to the said prescribed datum point between the channel waveguide that is number i and the one that is i + 1 in the said connecting section of the said input side slab waveguide or the said output side slab waveguide is gradually varied, as shown in equation (1) below.

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + \sum A_k \cdot |i - j| \cdot k\} \dots \dots \dots (1)$$

(In equation (1), A_k is a constant and k is an integer from 1~N.)

0024 [4] The optical wavelength multiplexer/branching filter disclosed in the said [3] where, in the said equation (1), the range of the prescribed constant A is made to be $-0.001 \leq A_k \leq 0.001$ (k is an integer from 1~N).

0025 [5] The optical wavelength multiplexer/branching filter disclosed in the said [3] or [4] where, in the said equation (1), by making the number (N) of channel waveguides forming the said array waveguide diffraction grating to be 1, the said angle $\Delta\theta_i$ is made to be the one shown in equation (2) below.

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + A_1 \cdot |i - j|\} \dots\dots\dots(2)$$

(In equation (2), A_1 is a constant and A_1 does not equal 0.)

0026

Form of Embodiment of the Invention

An explanation of a form of embodiment of this invention is given below in concrete terms, making reference to the diagrams. Fig.1 is an explanatory diagram which shows typically an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.1(a) is a diagram of the whole. Fig.1(b) is an expanded diagram of the array waveguide diffraction grating part. Here, as an example, an optical wavelength multiplexer/branching filter for combining and dividing 9 optical signals $\lambda_1 \sim \lambda_9$ ($\lambda_1 < \lambda_2 < \dots\dots\dots < \lambda_8 < \lambda_9$) is shown.

0027 As shown in Fig.1(a), it is composed, on substrate 101, of input waveguide 102 and input slab waveguide 104 and array waveguide diffraction grating 106, consisting of N channel waveguides 105 made longer sequentially by length ΔL shown in the said equation (3) from the shortest one to the longest one, and 9 output waveguides 108. Furthermore, mode conversion section 103 is formed in the connecting section for input waveguide 102 with input slab waveguide 104 in order to flatten the pass band characteristics of the loss wavelength characteristics.

0028 As shown in Fig.1(b), the various channel waveguides 105 that form array waveguide diffraction grating 106 are arranged in a radiating shape in the connecting section of input slab waveguide 104 and the connecting section of output waveguide 107 with respect to datum points 109 and 110 of input slab waveguide 104 and output slab waveguide 107. The angle $\Delta\theta$ that each channel waveguide 105 forms with its respective adjacent channel waveguides gradually changes from the bottom side (the B, C side) of the array waveguide diffraction grating as one goes towards the top side (the B', C' side). Here the angle $\Delta\theta_{i111}$, which number i channel waveguide of array waveguide diffraction grating 106 forms with the adjacent number i + 1 channel waveguide, is arranged so as to be as in equation (4) below with respect to the channel j waveguide, which is the datum, and its angular spacing $\Delta\theta_{j112}$.

$$\Delta\theta_i = \Delta\theta_j \cdot \{1 + A \cdot |i - j|\} \dots\dots\dots(4)$$

(In equation (4), i is the number in the channel waveguides forming the array waveguide diffraction grating, j the datum waveguide number, A an integer and A is not equal to 0.)

0029 In this invention, the number of channel waveguides 105 that form array waveguide diffraction grating 106 was made to be 60, the specified waveguide number j to be 30 and the angular spacing $\Delta\theta_{30}$, which this number 30 channel waveguide forms with the number 31 channel waveguide, to be 0.2 (deg.). Constant A was made to be 0.0002. Moreover, as constant A has a weak correcting effect if the absolute value of its value is weak and conversely has an over-strong correcting effect if it is too big, as shown in the said equation (1), it is desirable for it to be within a range from -0.001 to 0.001.

0030 Fig.2 is an explanatory diagram showing typically the electrical field distribution in a specific region of an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter, which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.2(a) shows electrical field distribution 113 of the optical signal at A-A' of mode conversion section 103. Fig.2(b) shows electrical field distribution 115 at B-B' of array waveguide diffraction grating incident end 114. Fig.2(c) shows electrical field distribution field 117 at C-C' of the array waveguide diffraction grating emitting end 116.

0031 Fig.3 is an explanatory diagram that shows typically the phase distribution of the optical signal in a specified region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter that is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.3(a) shows phase distribution 118 of optical signals λ_1 and λ_9 at B-B' of array waveguide diffraction grating incident end 114. Fig.3(b) shows phase distribution 119 of optical signals λ_1 and λ_9 at array waveguide diffraction grating emitting end 116.

0032 Fig.4 is an explanatory diagram showing typically the phase difference of optical signals in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter that is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.4(a) shows phase difference 120 between optical signals λ_3 and λ_1 . Fig.4(b), (c) and (d) respectively show the phase differences 121, 122 and 123 with optical signals λ_3 and λ_7 and λ_9 .

0033 Fig.5 shows respectively the electrical field distributions 125, 126, 127, 128 and 129 of optical signals λ_1 , λ_3 , λ_5 , λ_7 and λ_9 at condensing surface 124 of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter that is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Here, the waveguide length difference ΔL of

adjacent channel waveguides of array waveguide diffraction grating 106 is set up so as to satisfy the said equation (3).

0034 An explanation is given below of the action of the optical wavelength multiplexer/branching filter of this invention, using Fig.1 and also making reference to other appropriate diagrams.

0035 Optical signals $\lambda_1 \sim \lambda_9$ are propagated in the sequence of input waveguide 102, mode conversion section 103, input slab waveguide 104, array waveguide diffraction grating 106, output slab waveguide 107 and output waveguides 108. First of all, an explanation will be made about propagation from input waveguide 102 to array waveguide incident end 114.

0036 As shown in Fig.1(a), optical signals $\lambda_1 \sim \lambda_9$, which are incident from incident end 130, are propagated from input waveguide 102 to mode conversion section 103. Optical signals $\lambda_1 \sim \lambda_9$ are formed into twin peaked electrical field distribution 113 at A-A' of mode conversion section 103.

0037 As shown in Fig.1(b), optical signals $\lambda_1 \sim \lambda_9$ are widely spread out by the effect of diffraction in input slab waveguide 104. As shown in Fig.2(b), at B-B' of array waveguide diffraction grating incident end 114 the distribution has become 115, which has maximum and minimum values.

0038 As shown in Fig.3(a), phase distribution 118 becomes a shape that has distribution 129, partially shifted by an amount π , on account of the electrical field distribution in mode conversion section 103 being made a twin peaked shape.

0039 Next, an explanation will be given about the state of the optical signal from array waveguide diffraction grating 106 to output waveguides 108. Moreover, as the state of propagation in this part differs depending on the wavelength of the optical signal, an explanation will be given first of all for λ_3 , which satisfies the aforementioned equation (3) and then an explanation will be given about the other optical signals.

0040 As shown in Fig.1(b), optical signal λ_3 at B-B' of array waveguide diffraction grating incident end 114 is incident on each channel waveguide 106 [*sic – translator*], is divided and is propagated along the interior of the respective channel waveguides. It is again focussed into one at C-C' of array waveguide diffraction grating end 116.

0041 As shown in Fig.2(c), electrical field distribution 117 becomes a shape almost the same as that of electrical field distribution 115 at B-B' of incident end 114. With regard to phase distribution 119 shown in Fig.3(b), as optical signal λ_3 satisfies the aforementioned equation (3), it is symmetrical to left

and right exactly the same as before propagation in the array waveguide diffraction grating and it becomes a distribution where the phase is partially shifted by an amount π . Consequently, as shown in Fig.1(b), optical signal λ_5 comes to a focal point at datum point 110 on output slab waveguide 117.

0042 As shown in Fig.5, the electrical field distribution 127 becomes a shape that is virtually the same as the electrical field distribution 113 in mode conversion section 103 that is shown in Fig.2(a). In addition, as shown in Fig.1(b), optical signal λ_5 is propagated along the output waveguide that is connected to datum point 110 and is emitted from the output terminal.

0043 An explanation now follows about signals other than λ_5 . Here, an explanation is given as an example for the cases of optical signals λ_1 , λ_3 , λ_7 and λ_9 . As shown in Fig.1, optical signals λ_1 , λ_3 , λ_7 and λ_9 are also respectively divided by array waveguide diffraction grating 106 and propagated along respective channel waveguides 105. The electrical field distribution after propagation along array waveguide diffraction grating 106 is virtually the same as for the case for optical signal λ_5 .

0044 However, as shown in Fig.4(a), (b), (c) and (d), with regard to the phase distribution, this is a curved shape and it is also tilted overall. The degree of curvature and the tilt become bigger, the bigger the difference in wavelength from optical signal λ_5 . The overall tilt of the phase difference is because propagation constant β has a wavelength dispersion and the condensing position differs depending on this tilt. The phase difference becomes a curved shape because the spacing of channel waveguides 105 that form array waveguide diffraction grating 106 changes overall, as shown in the aforementioned equation (4) and it has an effect which offsets the aberrations in the output slab waveguide.

0045 Consequently, the various optical signals respectively condense at points $X_1 \sim X_9$ (not shown in the diagram) on D-D' of condensing surface 124 of output slab waveguide 107. Aberrations in the electrical field distributions 125, 126, 128 and 129 are also offset and each of the signals becomes a twin peaked shape that is symmetrical to right and left. In addition, each signal is incident on the various output waveguides 108, is propagated and can be extracted separately from output end 131 [sic – translator].

0046 Fig.6 is an explanatory diagram which shows typically the loss wavelength characteristics 132 [sic – translator] of an array waveguide diffraction grating type of optical wavelength multiplexer/branching filter, which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention.

0047 As shown in Fig.5 and Fig.6, the insertion loss of each output waveguide 108 is determined by the superimposed integrals of the individual modes of each output waveguide 108 and electrical field distributions 125, 126, 127, 128 and 129 of the optical signals at C-C' of condensing surface 124.

Electrical field distributions 125, 126, 127, 128 and 129 of the optical signals move on D-D' of condensing surface 124 according to the wavelength while maintaining their twin peaked shape. Because of this, even if the wavelength of the optical signal fluctuates slightly, the insertion loss does not change much. In other words, as shown in Fig.6, with regard to the loss wavelength characteristics 132 [sic – translator], as passing band 133 is flat and symmetrical to right and left even if wavelength fluctuations occur within passing band 133 in wavelengths $\lambda_1 \sim \lambda_9$ of the various optical signals, the insertion loss does not increase.

0048 Moreover, the substrate used in the optical wavelength multiplexer/branching filter of this invention can be formed not only with a glass substrate but also with a semiconductor and suchlike. Furthermore, the core, cladding and buffer layer formed on substrate 101 can be made not only with a glass material but also with semiconductor material, using optically transparent material.

0049

Effect of the Invention

As has been explained above, with the optical wavelength multiplexer/branching filter of this invention aberrations in the slab waveguide are offset by optimising the layout angle of each channel waveguide of the array waveguide diffraction grating at the input slab waveguide and the output slab waveguide and flat passing band characteristics can be realised in all the output waveguides. Therefore it is possible to provide a optical wavelength multiplexer/branching filter where loss fluctuations for wavelength fluctuations in the light source are small and stable optical signal combining and dividing is possible.

0050

Brief Explanation of the Diagrams

Fig.1 is an explanatory diagram showing typically the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.1(a) is a diagram of the whole. Fig.1(b) is an enlarged diagram of the array waveguide diffraction grating section.

Fig.2 is an explanatory diagram showing typically the electrical field distribution in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.2(a) shows electrical field distribution 113 of the optical signal at A-A' of mode conversion section 103. Fig.2(b) shows electrical field distribution 115 at B-B' of array waveguide diffraction grating incident end 114. Fig.2(c) shows electrical field distribution 117 at C-C' of array waveguide diffraction grating emitting end 116.

Fig.3 is an explanatory diagram showing the optical phase distribution in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of

1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.3(a) shows optical signal λ_1 and λ_9 phase distribution 118 at B-B' of array waveguide diffraction grating incident end 114. Fig.3(b) shows optical signal λ_1 and λ_9 phase distribution 119 at array waveguide diffraction grating emitting end 116.

Fig.4 is an explanatory diagram showing typically the optical phase difference in a specific region of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention. Fig.4(a) shows phase difference 120 between optical signals λ_1 and λ_5 . Fig.4(b), (c) and (d) respectively show phase differences 121, 122 and 123 between optical signal λ_5 and optical signals λ_3 , λ_7 and λ_9 .

Fig.5 shows respectively the electrical field distributions 125, 126, 127, 128 and 129 of optical signals λ_1 , λ_3 , λ_5 , λ_7 and λ_9 at condensing surface 124 of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention.

Fig.6 is an explanatory diagram showing typically loss wave characteristics 132 [*sic – translator*] of the array waveguide diffraction grating type of optical wavelength multiplexer/branching filter which is a form of 1 practical embodiment of the optical wavelength multiplexer/branching filter of this invention.

Fig.7 is an explanatory diagram showing typically a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

Fig.8 is an explanatory diagram showing typically electrical field distribution of the optical signal in specific regions of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.8(a) shows electrical field distribution 209 of the optical signal at E-E' of mode conversion section 203. Fig.8(b) shows electrical field distribution 211 at F-F' of array waveguide diffraction grating incident end 210. Fig.8(c) shows electrical field distribution 213 at G-G' of array waveguide diffraction grating emitting end 212.

Fig.9 is an explanatory diagram showing typically the phase distribution of the optical signal in specific regions of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter. Fig.9(a), 9(c) and 9(f) (*sic*) respectively show phase distribution 214, 215 and 216 for optical signals λ_1 , λ_5 and λ_9 at G-G' of array waveguide diffraction grating emitting end 212.

Fig.10 is an explanatory diagram showing typically the difference in optical signal phase distribution in specific regions of a conventional array waveguide diffraction grating type of optical wavelength

multiplexer/branching filter. Fig 10(a) and 10(b) show difference of phase distributions 217 and 218 which are respectively the difference between phase plane 215 of optical signal λ_3 and phase planes 214 and 216 of optical signals λ_1 and λ_9 .

Fig. 11 is an explanatory diagram showing typically electrical field distributions 220, 221 and 222 of optical signals λ_1 , λ_3 and λ_9 at H-H' of condensing surface 219 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

Fig. 12 is an explanatory diagram showing typically loss wavelength characteristics 224, 225, 226 and 227 of a conventional array waveguide diffraction grating type of optical wavelength multiplexer/branching filter.

Explanation of the Symbols

- 101 substrate
- 102 input waveguide
- 103 mode conversion section
- 104 input slab waveguide
- 105 channel waveguide
- 106 array waveguide diffraction grating
- 107 output side slab waveguide
- 108 output waveguide
- 109 datum point
- 110 datum point
- 111 angle made by number i channel waveguide with number i + 1 channel waveguide
- 112 angle made by specified number j channel waveguide with number j + 1 channel waveguide
- 113 electrical field distribution of the optical signal in the mode conversion section
- 114 array waveguide diffraction grating incident end
- 115 electrical field distribution of the optical signal at the array waveguide diffraction grating incident end
- 116 array waveguide diffraction grating emitting end
- 117 electrical field distribution of the optical signal at the array waveguide diffraction grating emitting end
- 118 phase distribution of optical signals $\lambda_1 \sim \lambda_9$ at the array waveguide diffraction grating incident end
- 119 phase distribution of optical signal λ_3 at the array waveguide diffraction grating emitting end
- 120 difference in phase distribution of optical signal λ_3 and phase distribution of

	optical signal λ_1 at the array waveguide diffraction grating emitting end
121	difference in phase distribution of optical signal λ_3 and phase distribution of
	optical signal λ_5 at the array waveguide diffraction grating emitting end
122	difference in phase distribution of optical signal λ_7 and phase distribution of
	optical signal λ_9 at the array waveguide diffraction grating emitting end
123	difference in phase distribution of optical signal λ_9 and phase distribution of
	optical signal λ_5 at the array waveguide diffraction grating emitting end
124	condensing surface
125	electrical field distribution of optical signal λ_1 at the condensing surface
126	electrical field distribution of optical signal λ_3 at the condensing surface
127	electrical field distribution of optical signal λ_5 at the condensing surface
128	electrical field distribution of optical signal λ_7 at the condensing surface
129	electrical field distribution of optical signal λ_9 at the condensing surface
130	focal position of optical signal λ_5
131	focal position
132	output end
133	pass band
201	substrate
202	input waveguide
203	mode conversion section
204	input slab waveguide
205	channel waveguide
206	array waveguide diffraction grating
207	output side slab waveguide
208	output waveguide
209	electrical field distribution of the optical signal in the mode conversion section
210	array waveguide diffraction grating incident end
211	electrical field distribution of the optical signal at the array waveguide diffraction
	grating incident end
212	array waveguide diffraction grating emitting end
213	electrical field distribution of the optical signal at the array waveguide diffraction
	grating emitting end
214	phase distribution of optical signal λ_1 at the array waveguide diffraction grating
	emitting end
215	phase distribution of optical signal λ_3 at the array waveguide diffraction grating
	emitting end
216	phase distribution of optical signal λ_9 at the array waveguide diffraction grating

- emitting end
- 217 difference between the phase distribution of optical signal λ_3 and the phase
distribution of optical signal λ_1 at the array waveguide diffraction grating emitting end
- 218 difference between the phase distribution of optical signal λ_3 and the phase
distribution of optical signal λ_9 at the array waveguide diffraction grating emitting end
- 219 condensing surface
- 220 electrical field distribution of optical signal λ_1 at the condensing surface
- 221 electrical field distribution of optical signal λ_3 at the condensing surface
- 222 electrical field distribution of optical signal λ_9 at the condensing surface
- 223 output end
- 224 loss wavelength characteristics of number 5 output waveguide
- 225 loss wavelength characteristics of number 1 output waveguide
- 226 loss wavelength characteristics of number 9 output waveguide
- 227 passing band
- 228 number 5 output waveguide

[Diagram Captions]

- [Fig.2] [y-axis] Electrical Field Strength
- [Fig.3] [y-axis] Phase (rad)
- [Fig.4] [y-axis] Phase (rad)
- [Fig.5] [y-axis] Light Strength
- [Fig.6] [y-axis] Loss
- [Fig.8] [y-axis] Electrical Field Strength
- [Fig.9] [y-axis] Phase (rad)
- [Fig.10] [y-axis] Phase (rad)
- [Fig.11] [y-axis] Light Strength
- [Fig.12] [y-axis] Loss [x-axis] Wavelength

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